Managed Aquifer Recharge

Water Policy Interim Committee

MBMG

Ginette Abdo
January 16-17, 2024

Montana Bureau of Mines and Geology

Montana's State Geologic Survey

- **Established in 1919 to provide reliable and unbiased earth science information**
- **Non regulatory, applied research**

- Geologic Mapping
- Ground Water
- Earthquake Studies/Geohazards
- Economic Geology
- Environmental Assessment
- Data Preservation

All data publicly available through web applications and published reports
https://www.mbmg.mtech.edu/

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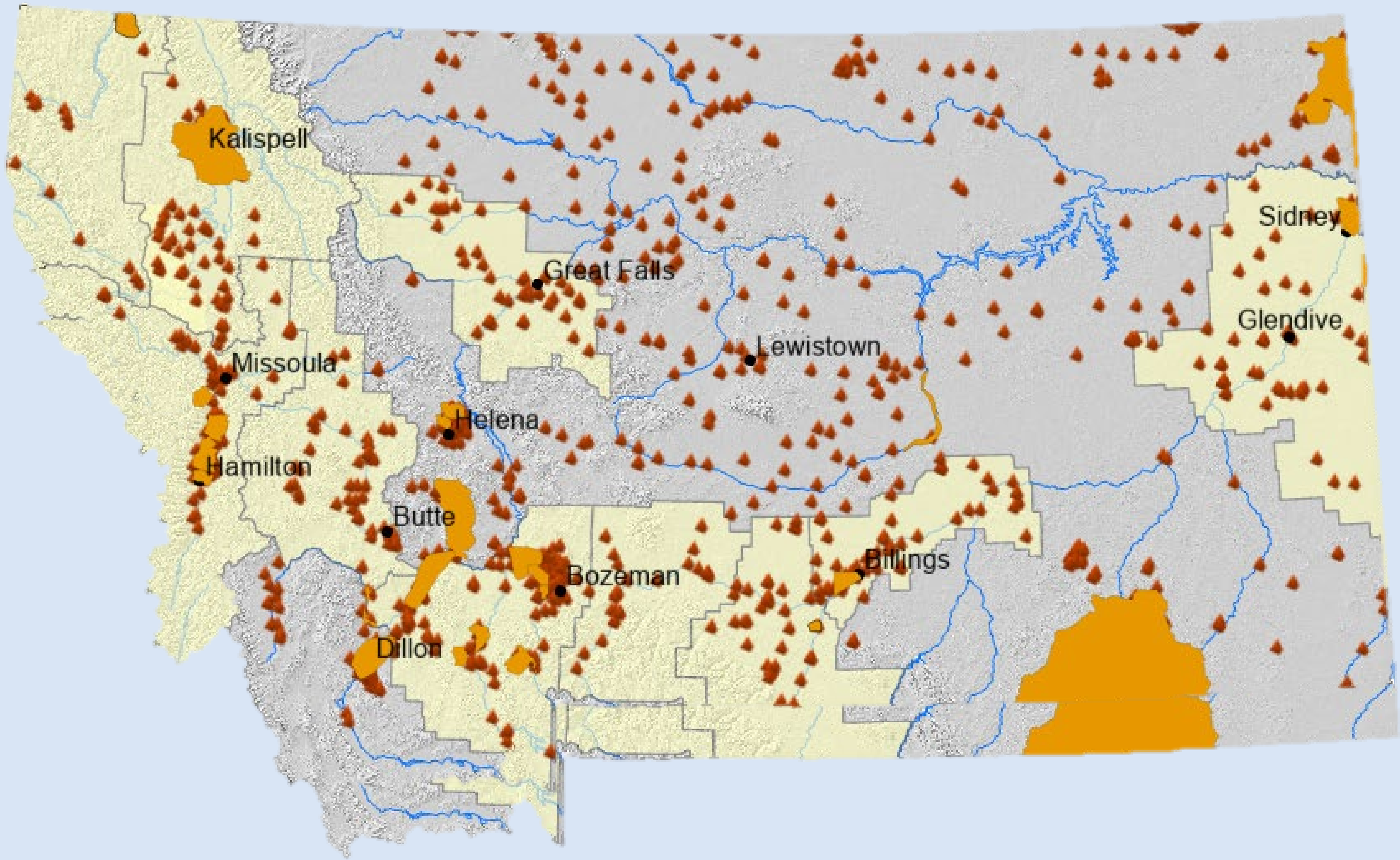
MBMG Ground Water Programs



- Ground Water Assessment Program
- Ground Water Investigation Program
- Numerous other project areas

Outline

- Background
  - Montana Geology
  - Managed Aquifer Recharge terminology
  - Aquifer types
- Managed Infiltration
  - Infiltration basins
- Aquifer Storage and Recovery
  - The process
- Advancing MAR in Montana

Hydrogeologic Focus

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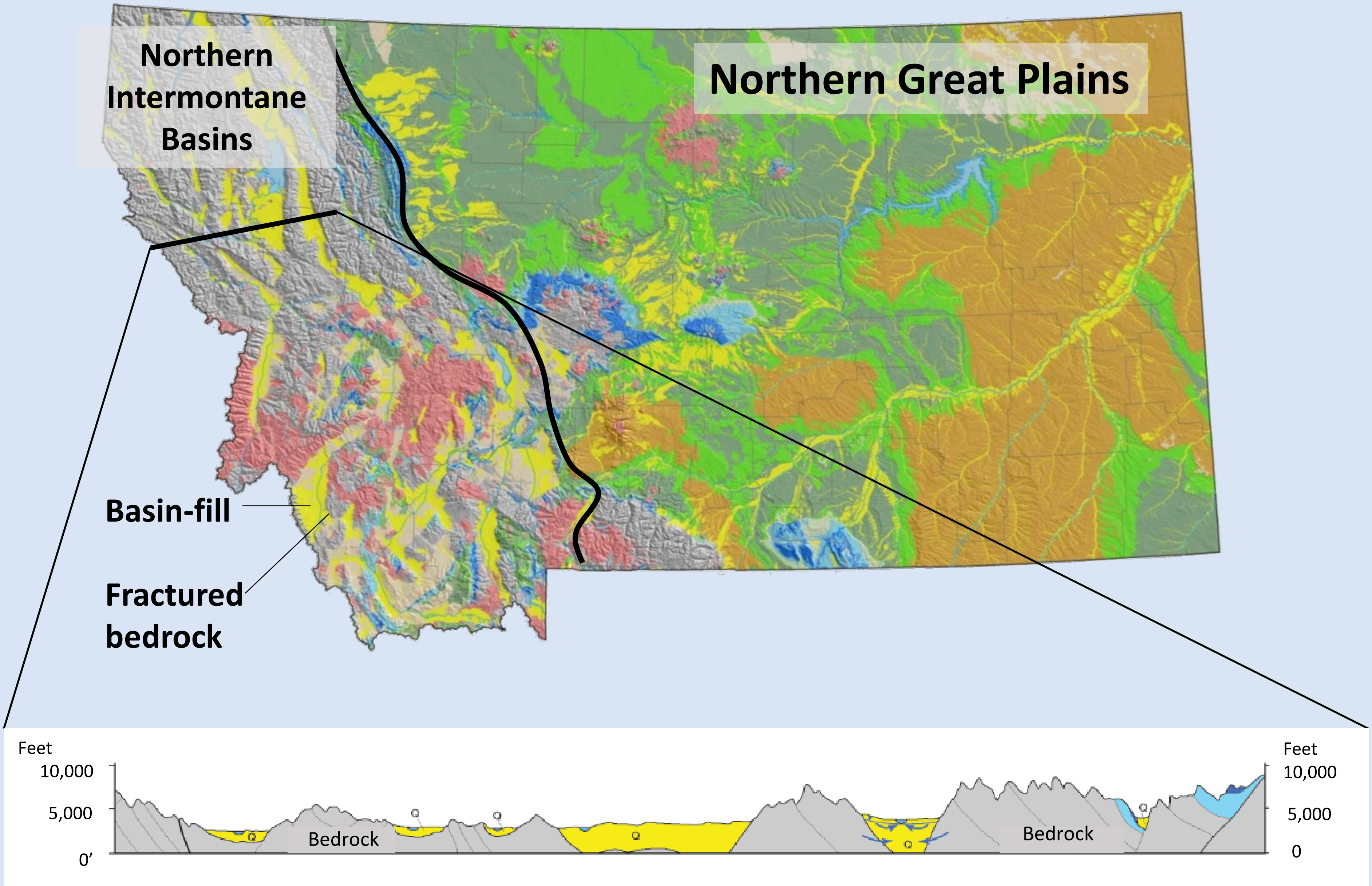
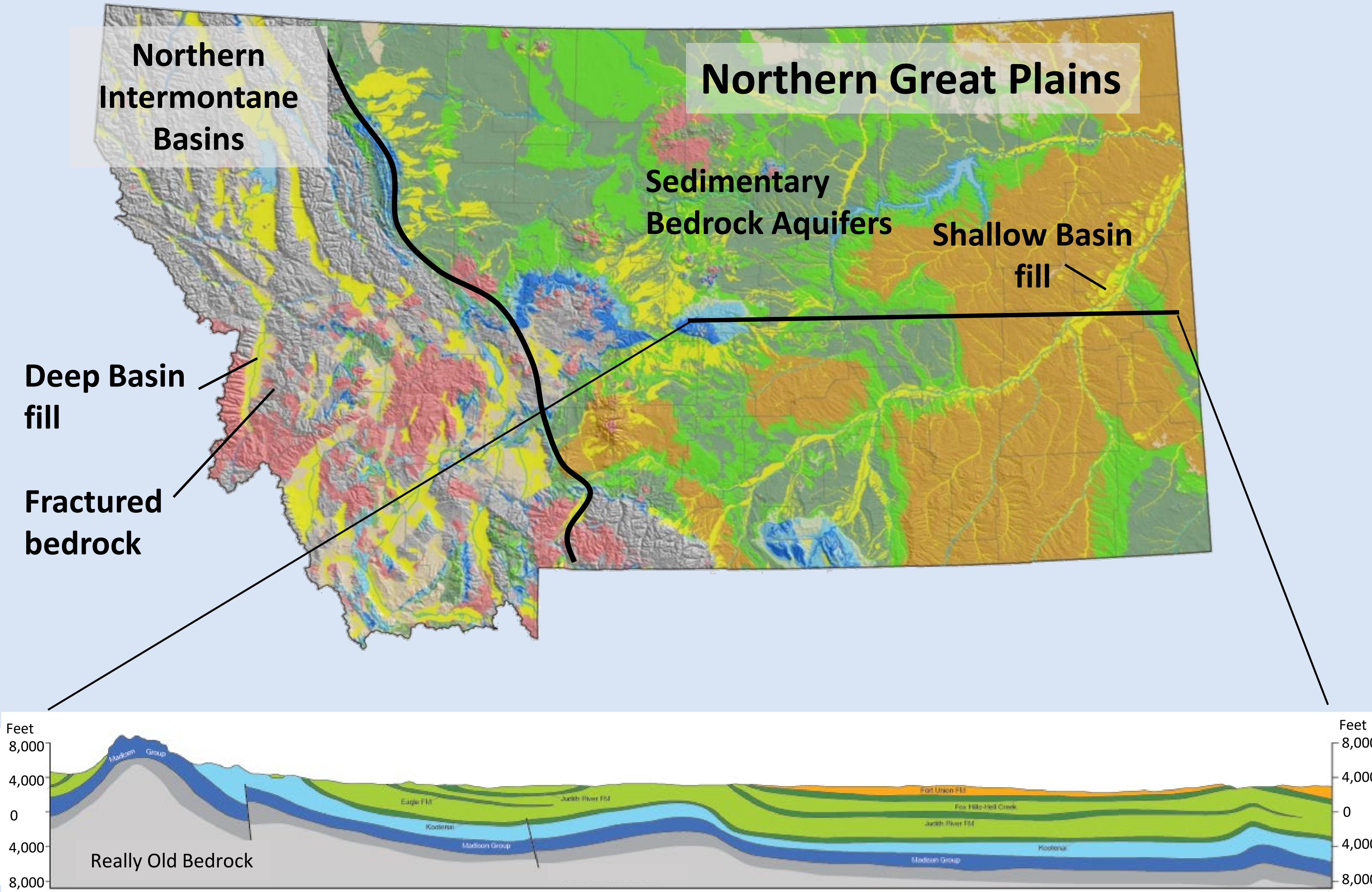
Geology



Northern Intermontane Basins
Northern Great Plains
Basin-fill
Fractured bedrock
Feet
10,000
5,000
0'
Bedrock
Bedrock
Feet
10,000
5,000
0

Geology and Aquifers



Terminology

Managed Aquifer Recharge (MAR)

Intentional banking or storing of water in aquifers

Managed Infiltration (MI)

- Surface techniques that involve land application including infiltration galleries

Aquifer Storage and Recovery (ASR)

- Recharge and recovery using water wells to increase off peak storage

Hybrids

- Managed Infiltration → Aquifer Storage and Recovery

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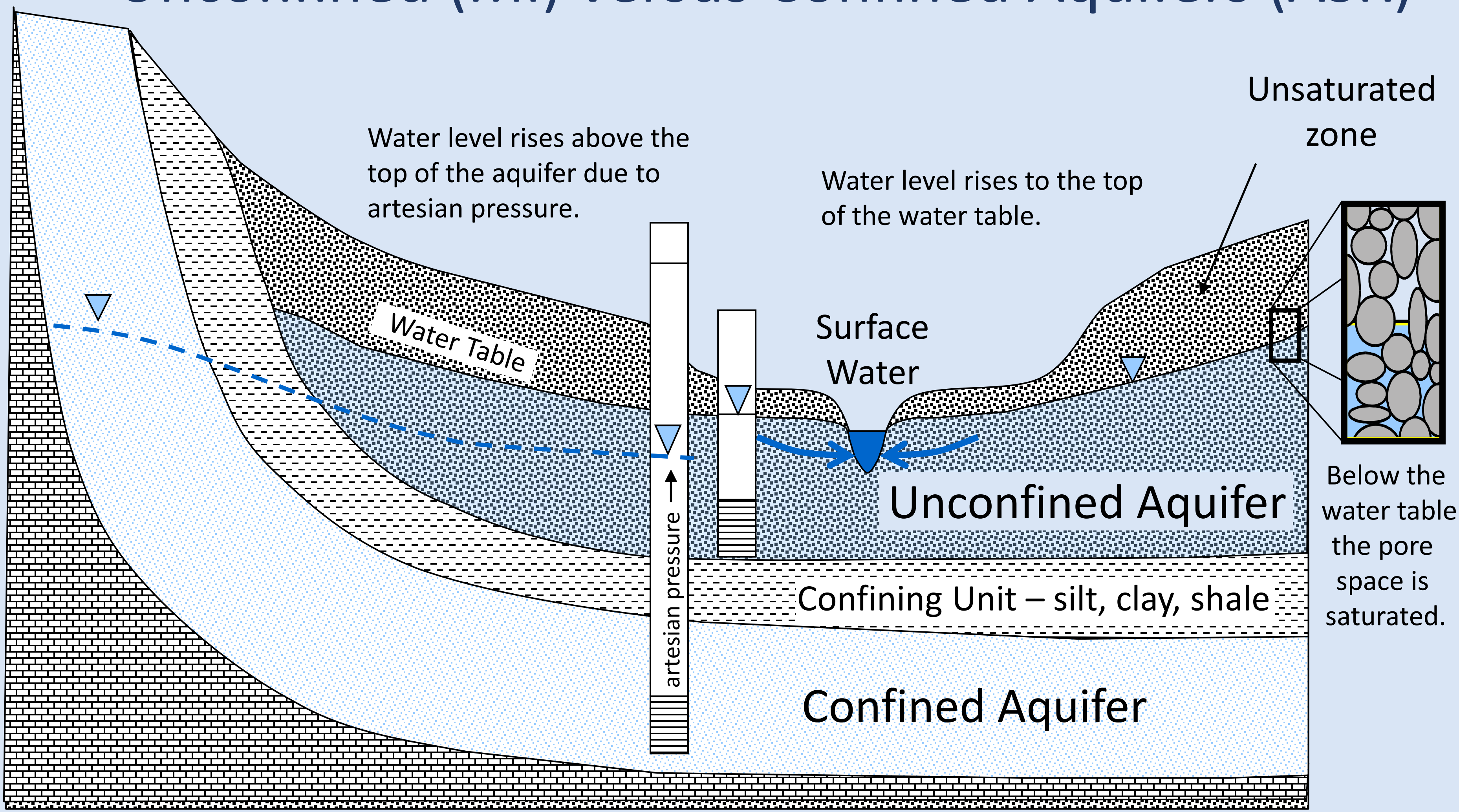
Terminology

Unconfined (MI) versus Confined Aquifers (ASR)



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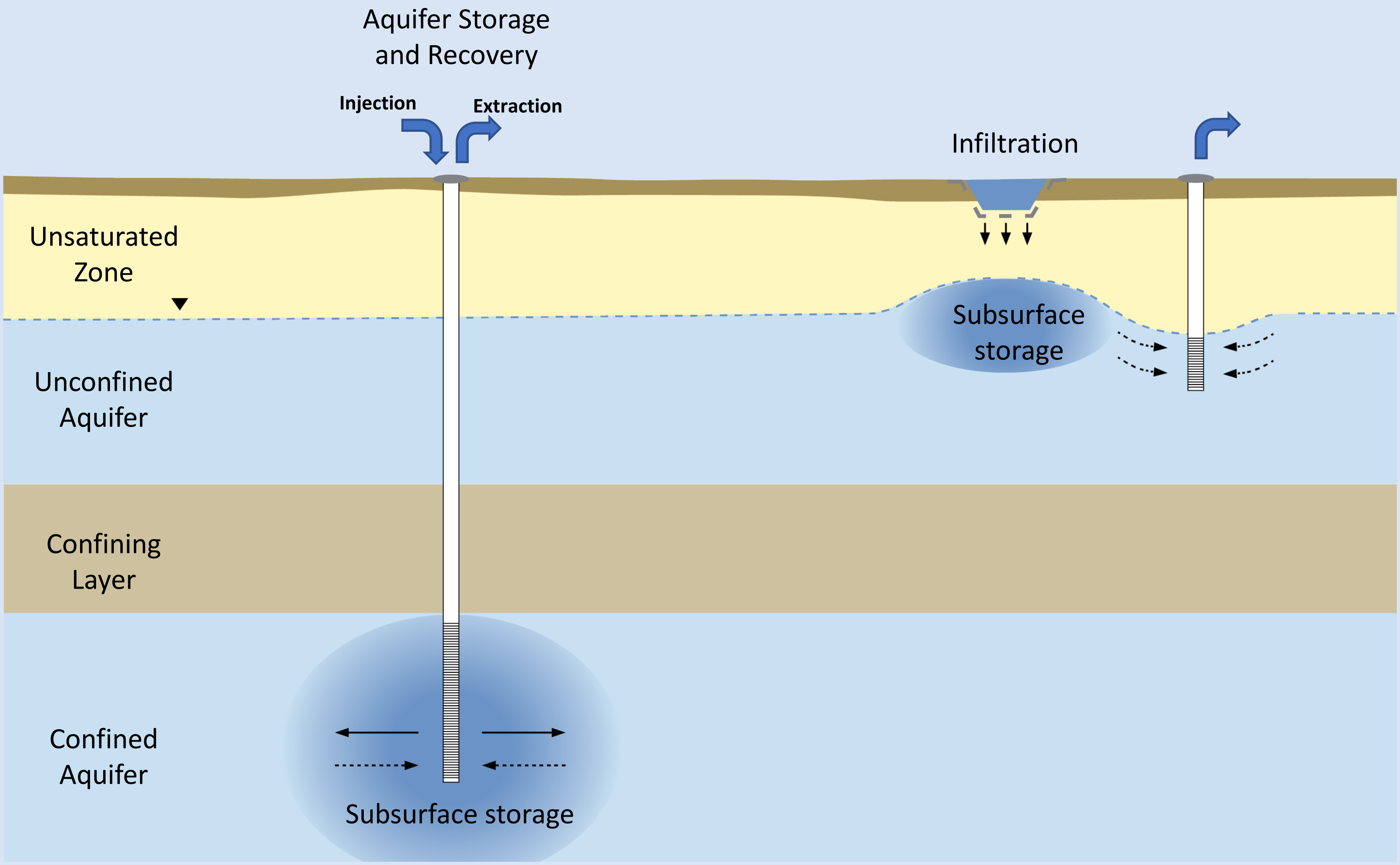
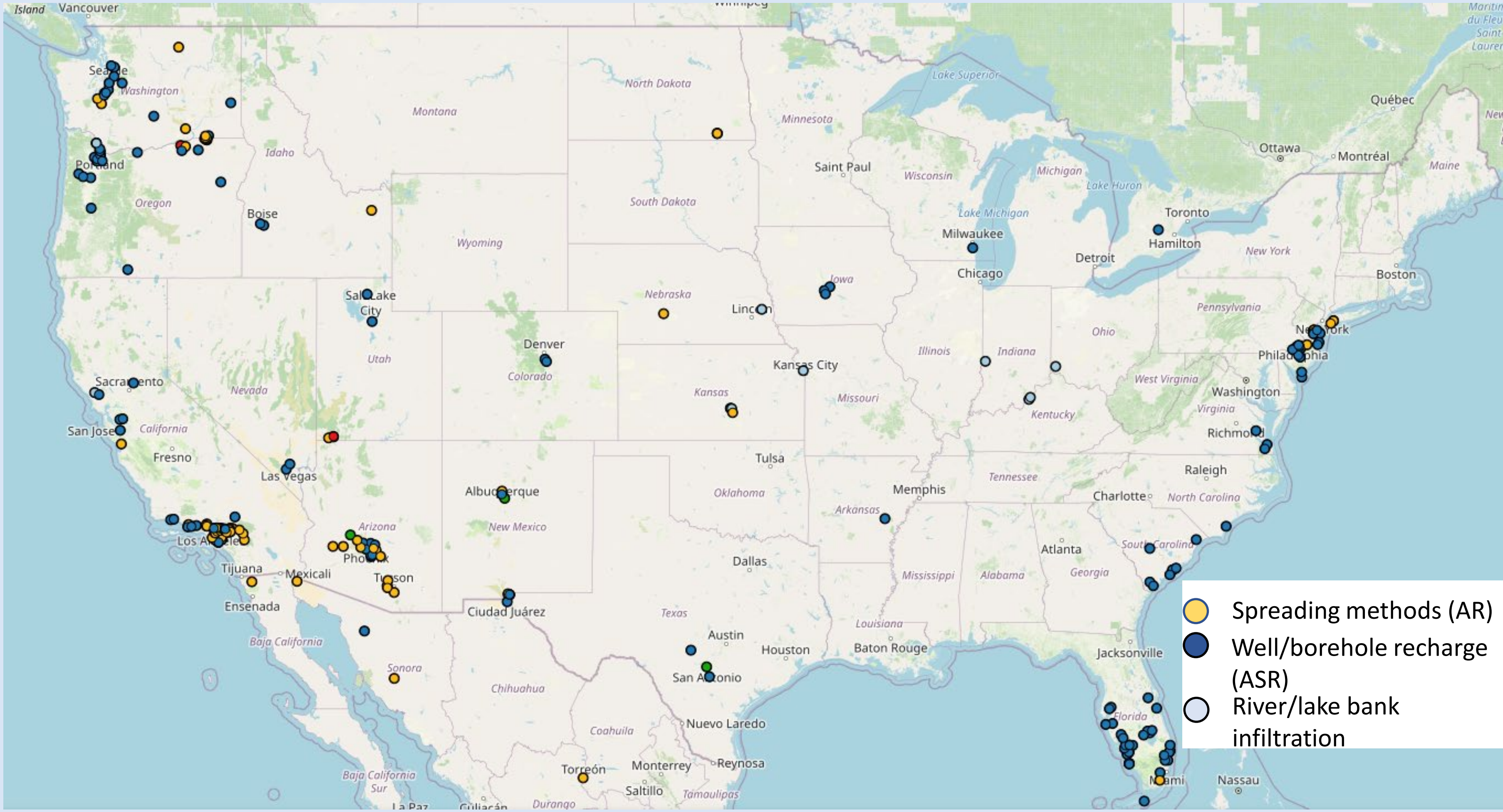
Managed Aquifer Recharge



MAR in the US



The Global Groundwater Information System (GGIS) – MAR Portal

https://ggis.un-igrac.org/view/marportal/

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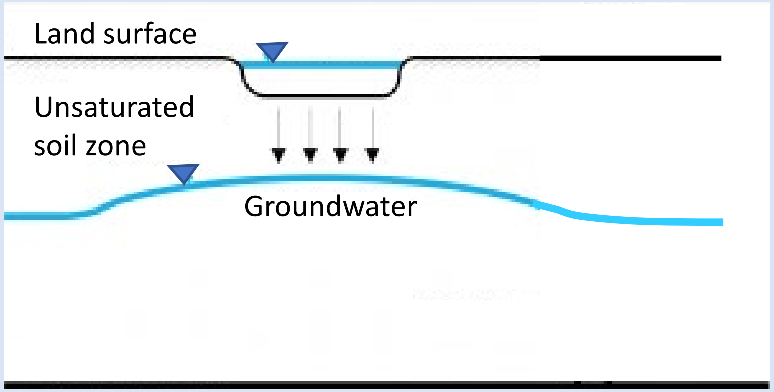
Managed Infiltration (MI)

Infiltration Basins



Unconfined aquifer

Continuous water release

Capture water quickly
BUT

- Expensive
- Require a lot of land
- Evaporation
- Sediment issues
- Can have environmental opposition

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Managed Infiltration (MI)

Site screening considerations

Surface spreading

Location
- Land ownership
- Distance of site to:
    - Water source
    - Service area –
      Where do you need the water?
    - Three phase power
    - Environmental issues

Surface conditions
- Topography
- Surficial geology
- Soil permeability
- Engineering and cost related issues

Sub-surface conditions (hydrogeology)
- Depth to groundwater (potential storage)
- Aquifer type and permeability
- Groundwater quality

From: Michael Milczarek, April 23, 2023 Session 8; Design and Operations Considerations

From: Michael Milczarek, April 23, 2023 Surface Spreading Groundwater Recharge projects Workshop

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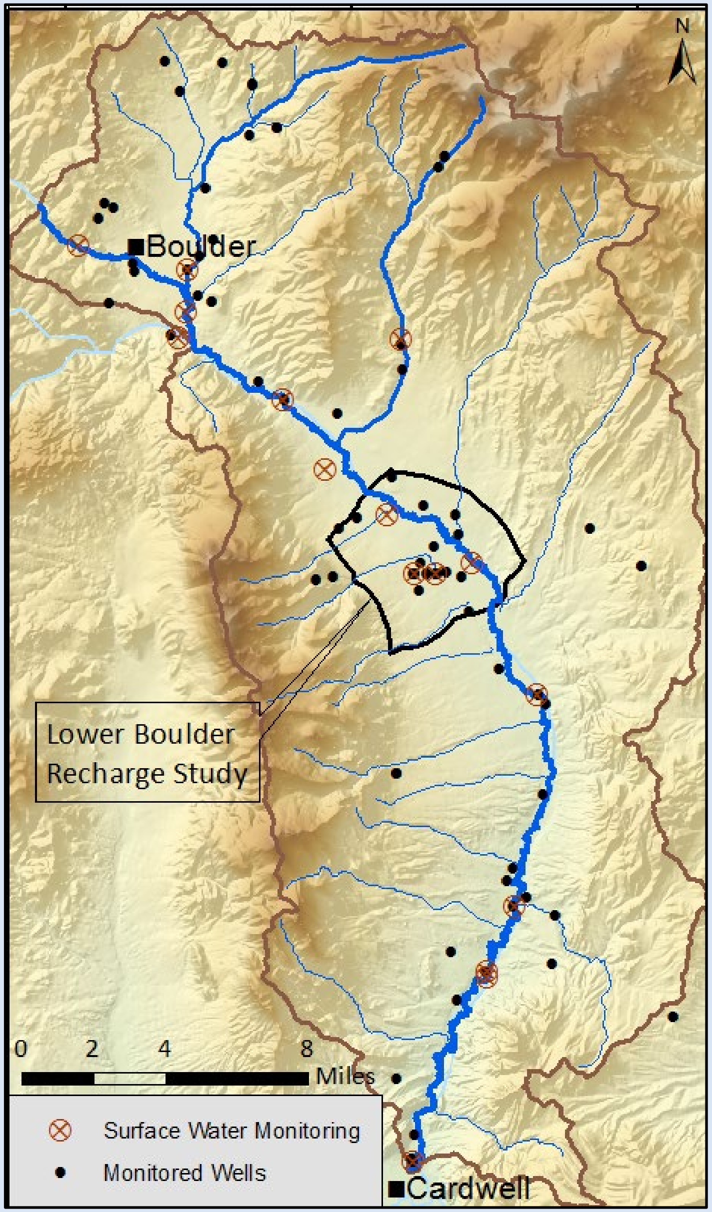
Infiltration Basins



Bobst and Butler, 2016, MBMG 682

Boulder River Watershed

Appropriations exceed physical supply in most years

Boulder River runs dry in the late irrigation season – just when water is needed most

Lower Jefferson Watershed Council

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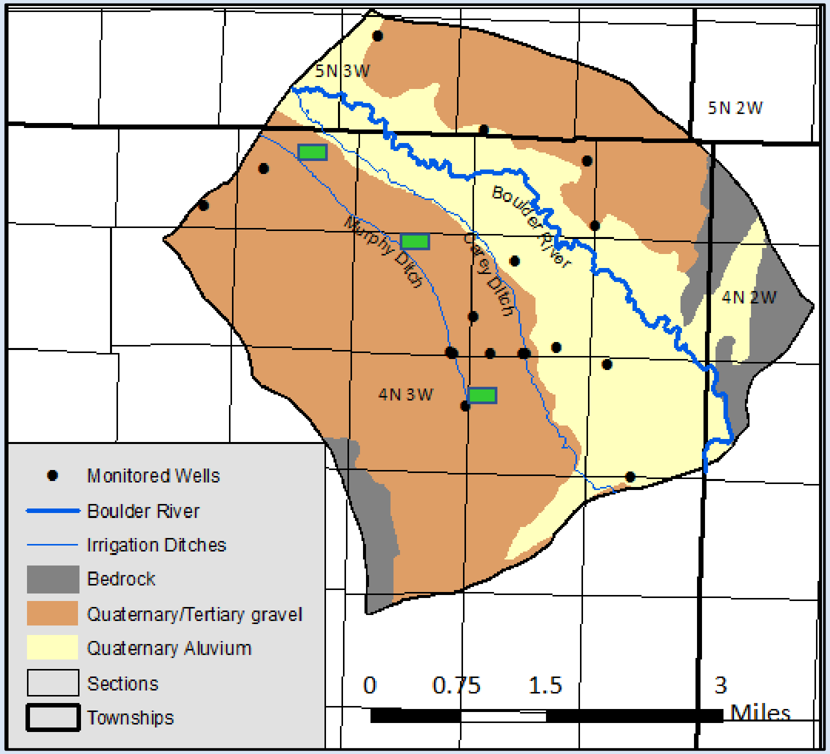
Boulder River Watershed



Infiltration basin (3.1 acres each)

Infiltration Basin simulations

- 3.1 acres
- Water added for 55 days (Mar 15 – May 9)
- Total flux infiltrated 691,200 cfd (8 cfs)

Model year 20

- Predicted groundwater flow to the Boulder River flow increased by an average annual rate of 103,680 cfd (1.2 cfs) – mostly during Jul – Sept.
- Size and location determines amount of recharge, and timing effects on surface water

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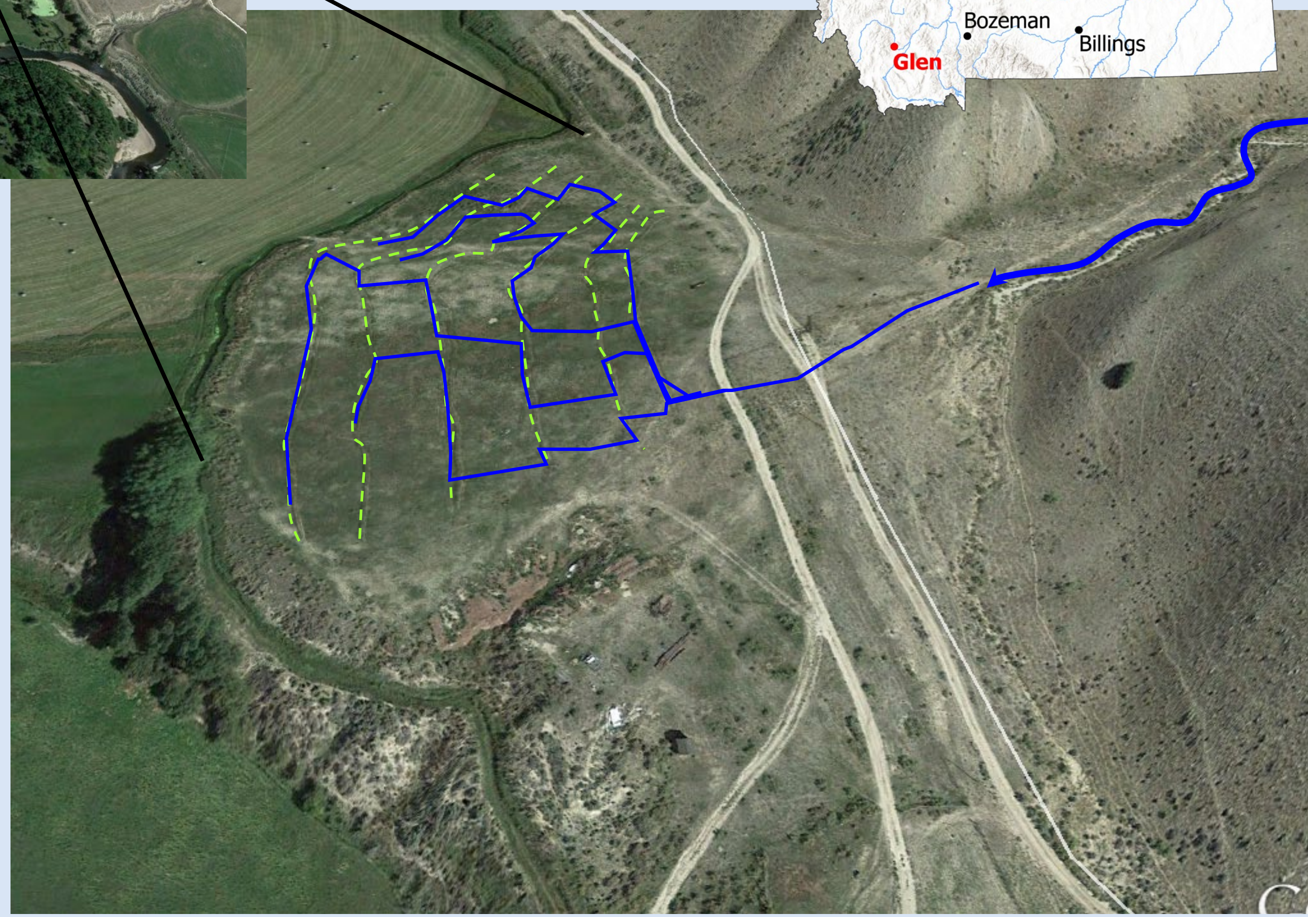
Spreading… slowing water down



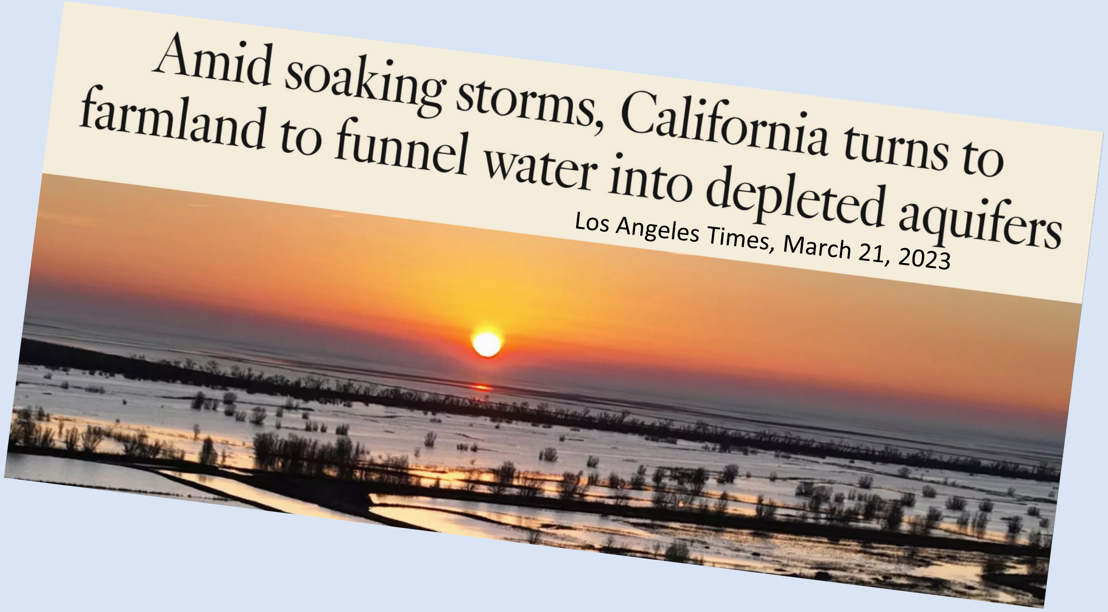
Glen, Montana

A local water steward

Agricultural MAR

Utilizes agricultural land and infrastructure to augment groundwater recharge

- Relies on water conveyance through existing canals, ditches, creeks, turnouts, and agricultural fields.
- Water available for recharge depends on climatic conditions and site-specific regulations such as minimum in-stream flow requirements or surface-water rights.



Agricultural Groundwater Recharge, University of California, Davis

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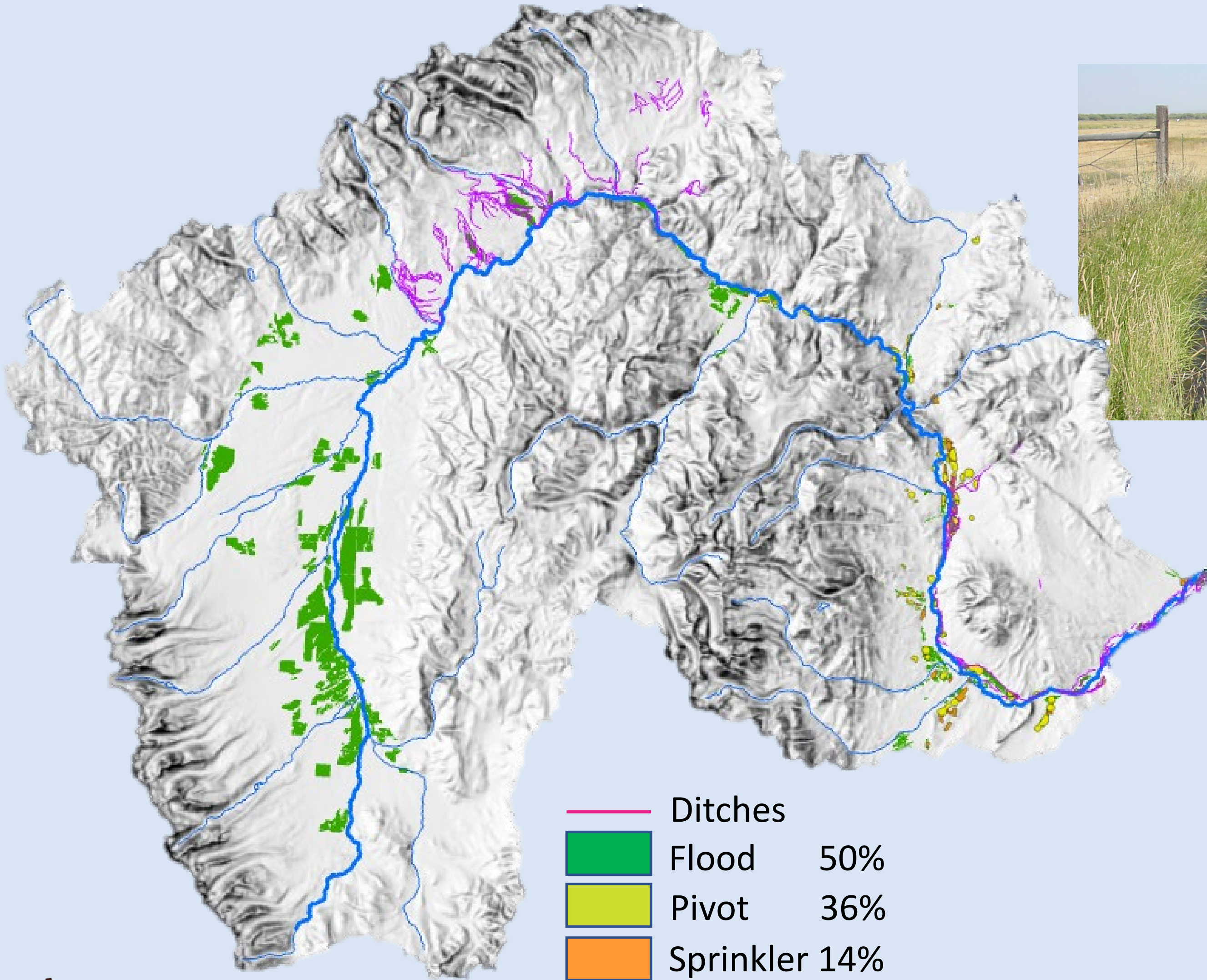
Agricultural MAR

Big Hole River Watershed



Total Irrigated acres
3,177 mi^2

Ditches
257 miles
(excluding Beaverhead County)

Ditch Leakage
(MBMG: Marvin and Voeller, 1997)
0.6 cfs/ mile (average loss)
.05 to 3.4 cfs/mile (range)

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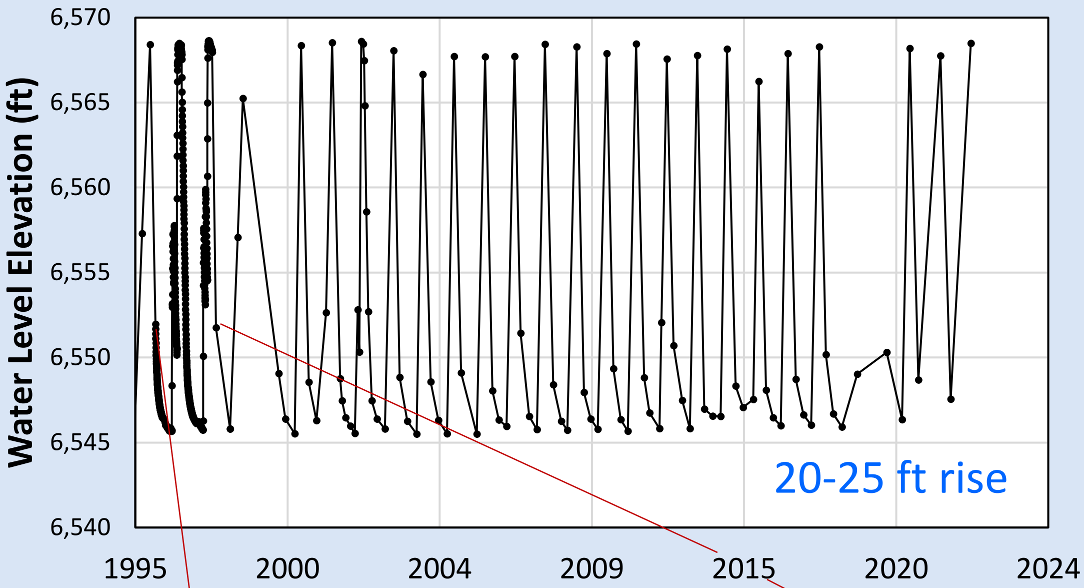
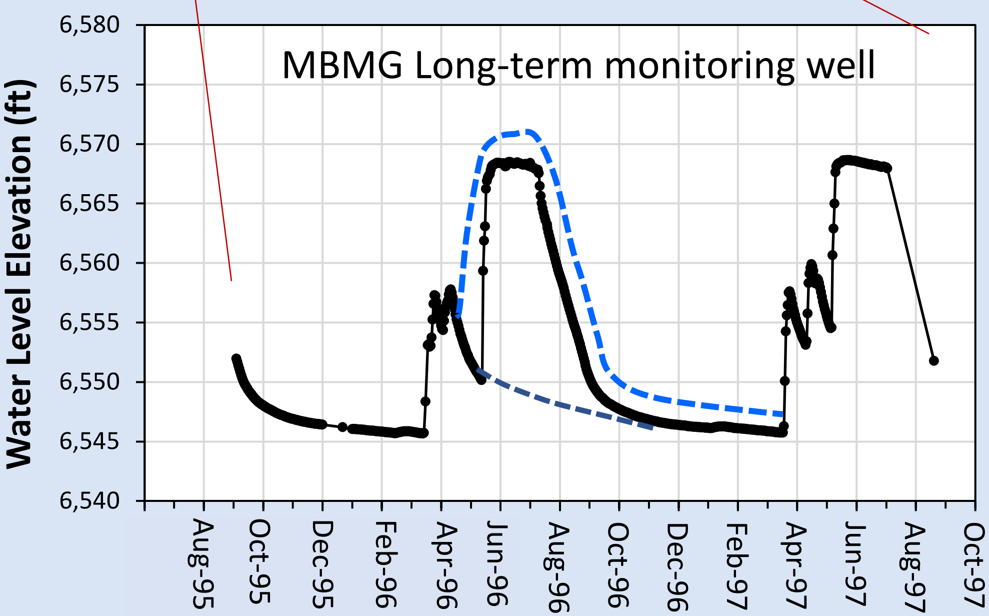
Irrigation recharge





Unintentional consequence

Beaverhead River – An Example

Purpose

Determine if high capacity irrigation wells will deplete surface water.

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Modeling Scenario

Running Water one-month before and one-month after the irrigation season

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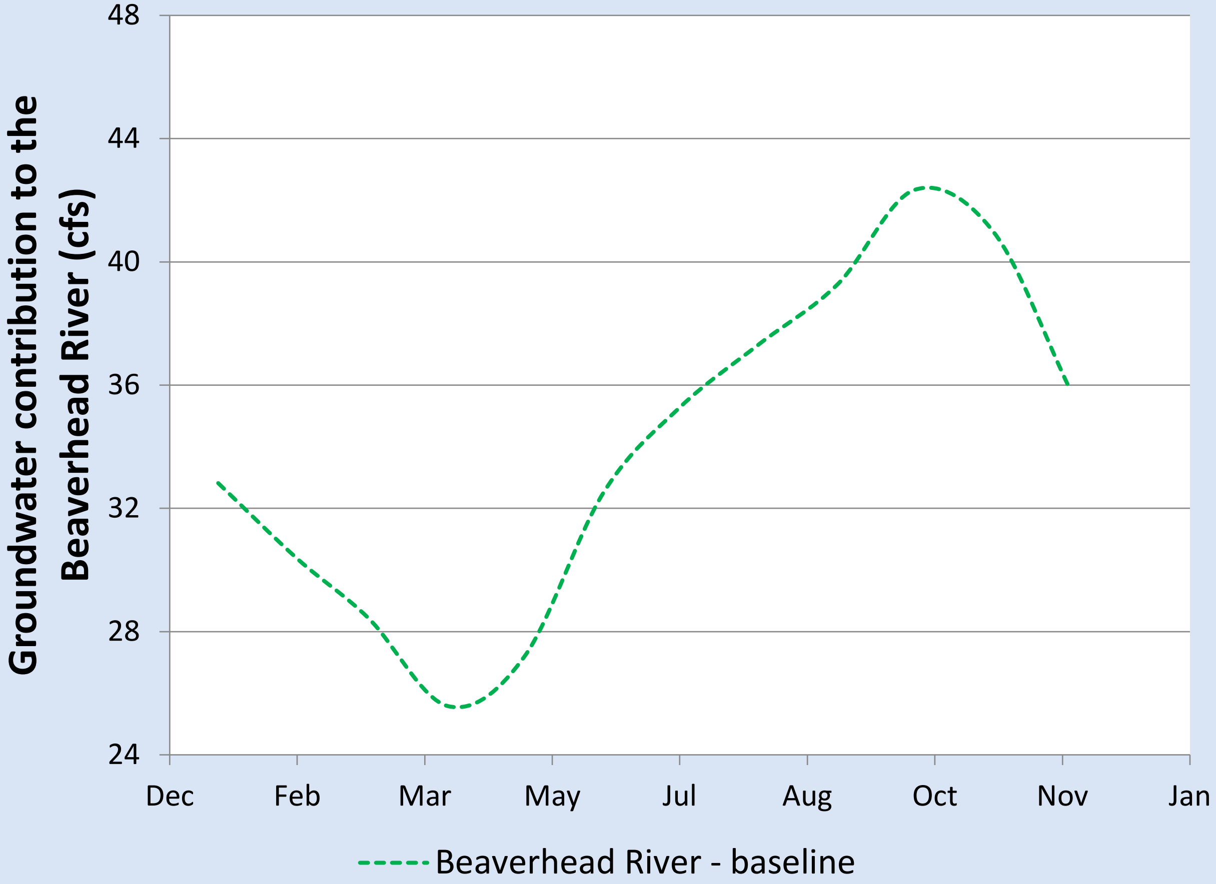
Agricultural MAR



Baseline Scenario

No wells pumping

Abdo and others, 2012, MBMG 637

Final year of simulation – Year 20

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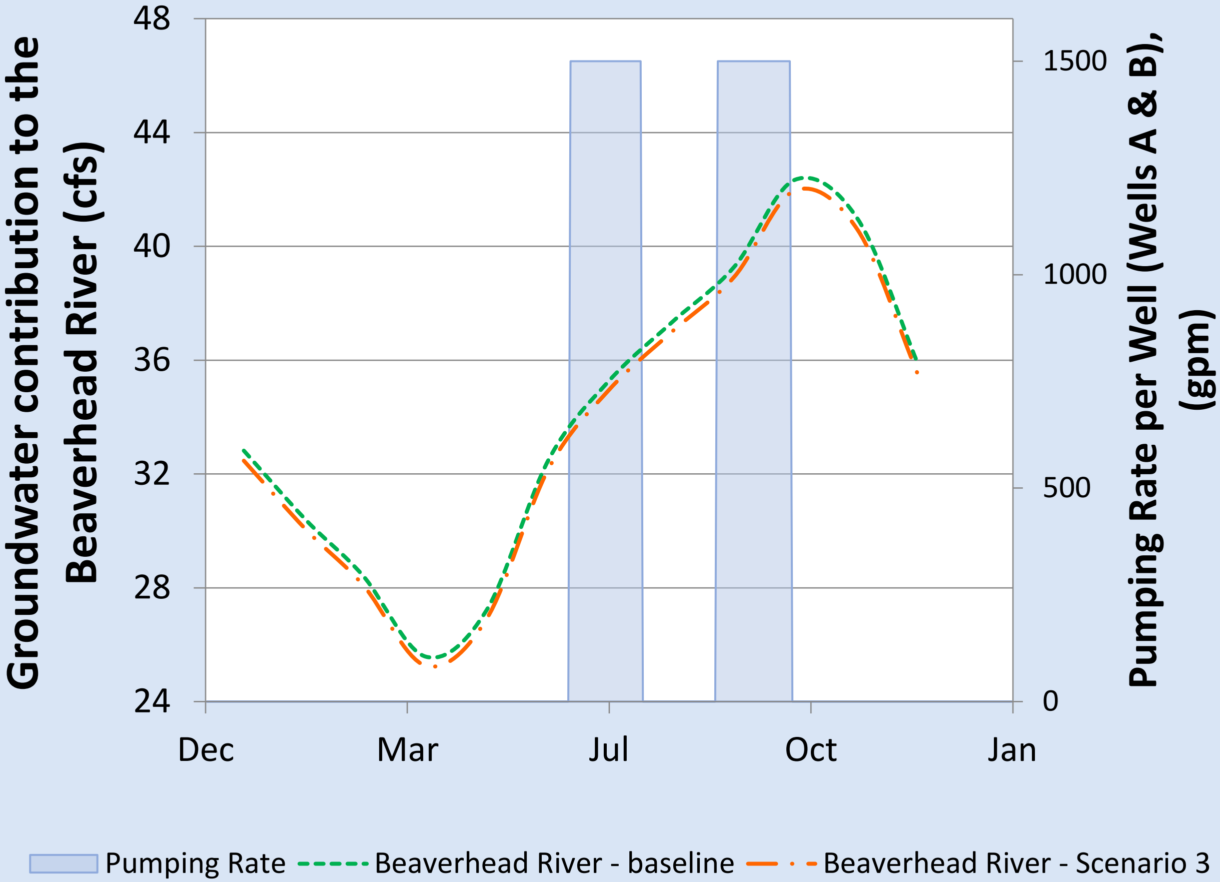
Agricultural MAR



Scenario:

Two wells pumping for two months at 1,500 gpm.

Final year of simulation – Year 20

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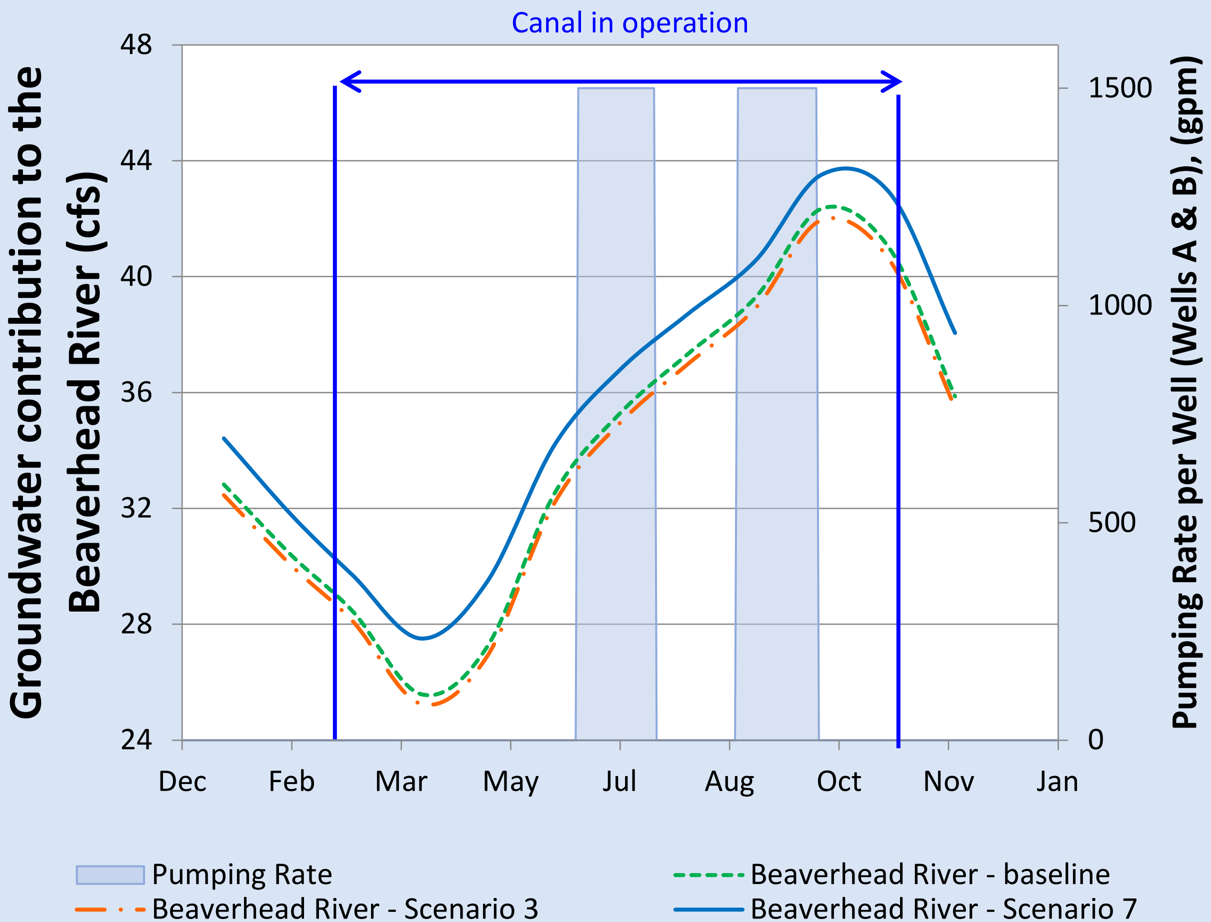
Agricultural MAR



Final year of simulation – Year 20

Abdo and others, 2012, MBMG 637

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Scenario:

Pumping

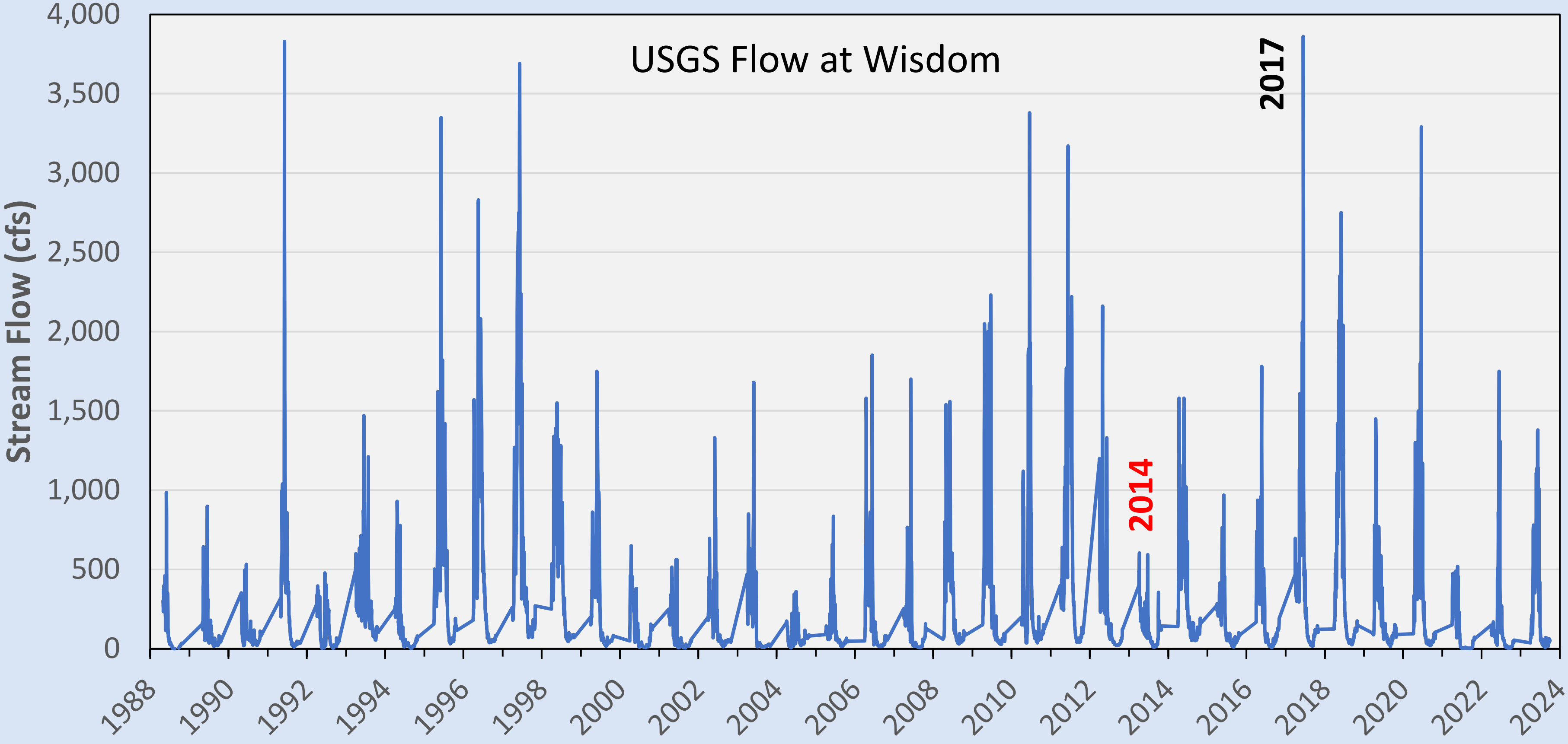
- Two wells pumping for two months at 1,500 gpm.

Canal recharge

- Running canal one month before and after the irrigation season.
- Canal recharge greater effect then pumping wells

Availability of Excess Water

When, where, and how much surface water is available?



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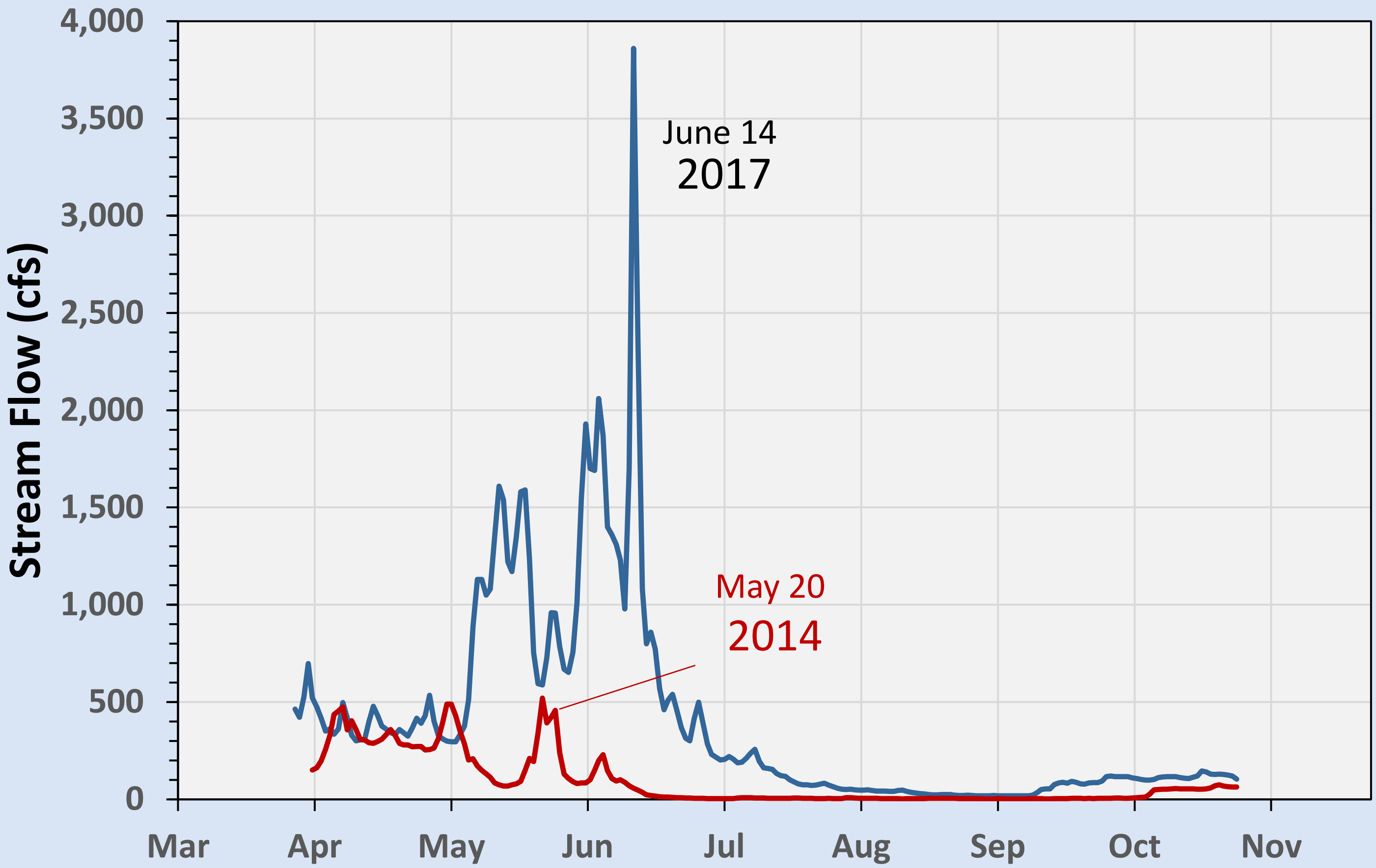
USGS Big Hole River Flow at Wisdom



How much flow is available for capture?

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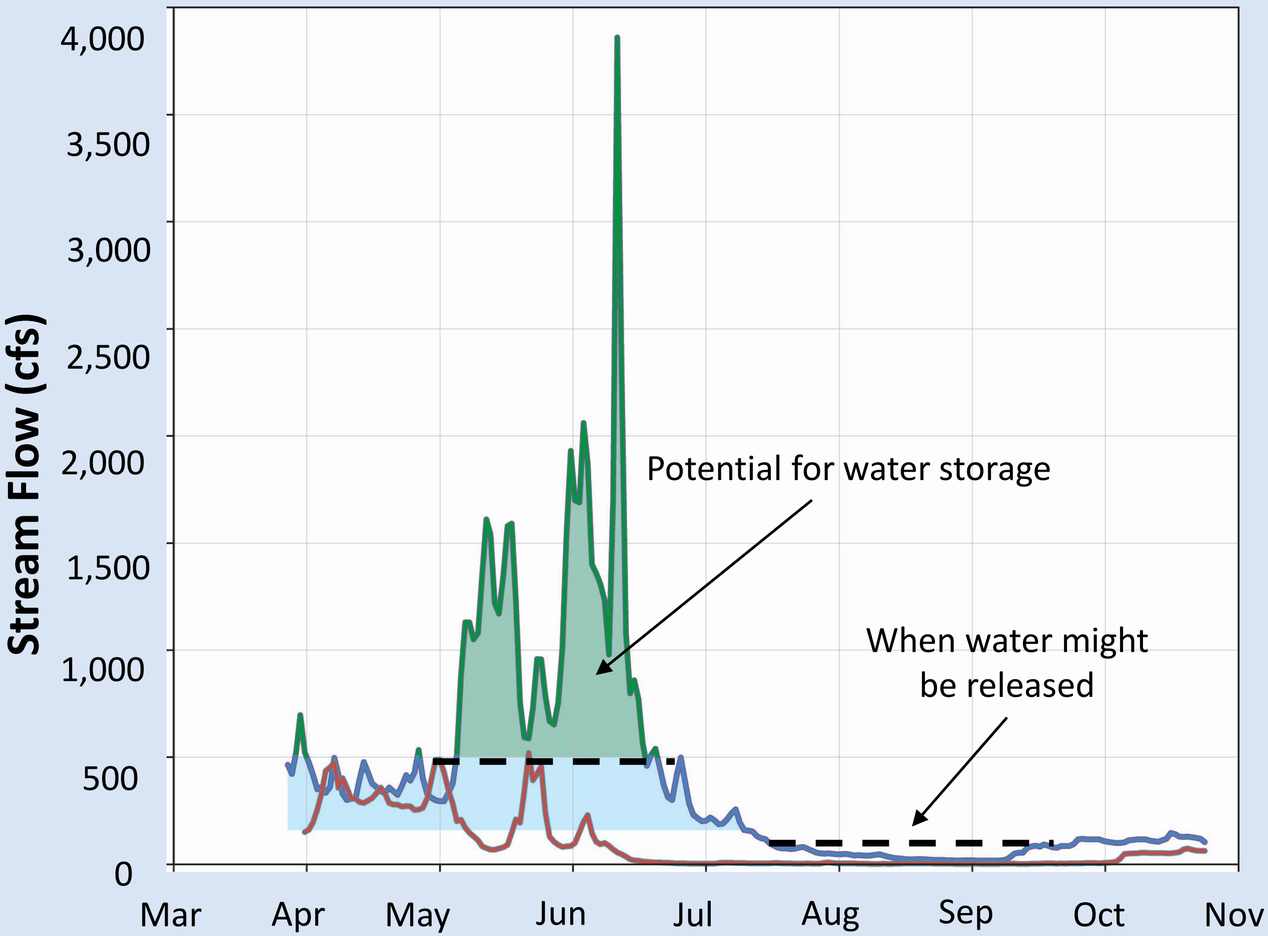
Availability of Excess Water



When, where, and how much surface water is available?

Physically and legally available.

- Main stem
- Tributaries

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Agricultural MAR

Considerations

- **Source water**
  - water availability, quality, microbiology, nutrient loads to groundwater
- **Conveyance structures**
- **Soil and unsaturated zone processes**
  - Soil properties, infiltration rates, soil clogging
  - High sediment loading in river
  - Soil leaching (i.e. nitrates, salts)
  - Potential anoxic (low oxygen) conditions with extended flooding
  - Inorganic contaminants such as arsenic
  - Potential lower soil fertility
- **Crop suitability**
- **Impact on groundwater**
- **Regulatory**
- **Economic costs**

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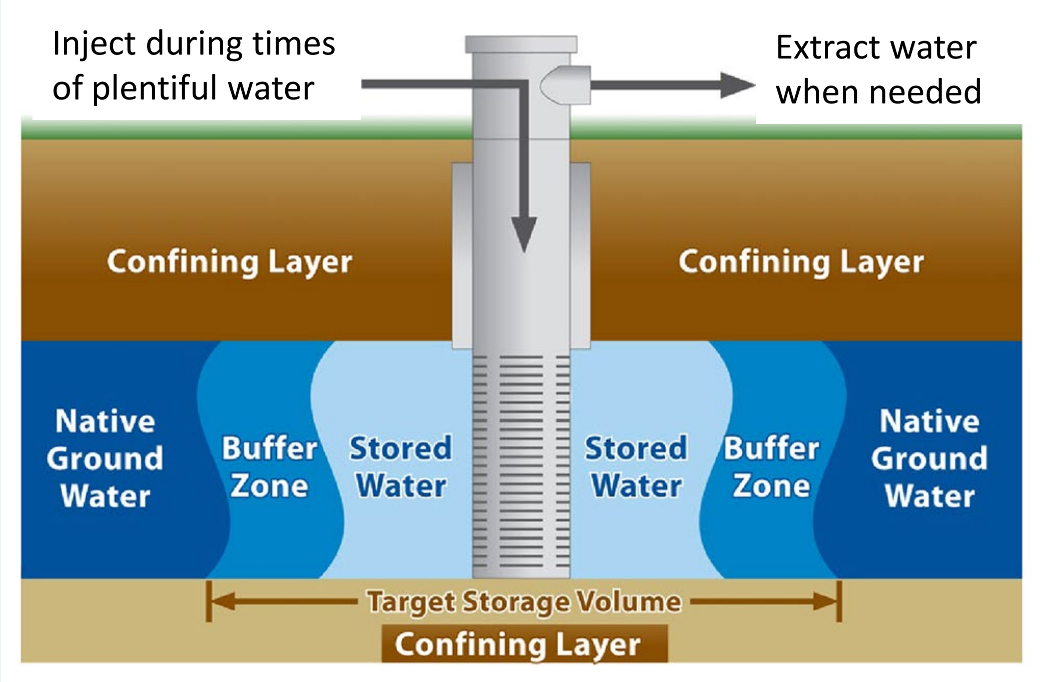
Aquifer Storage and Recovery (ASR)

- Water moved into an aquifer by well injection
- Recovered from the same well (or nearby well)

- To do this…
  - hydrogeology
  - engineering
  - permitting
  - infrastructure



https://www.card.iastate.edu/ag_policy_review/article/?a=126

Target Storage Volume = stored water and buffer zone

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Feasibility study

- **Defines the objectives**
  - Timeframe of need
  - Volume of water to meet needs
- **Source of recharge water**
  - Average flow, monthly variability
  - Proximity to aquifer
- **Hydrogeology**
  - ✓ **Overall site stratigraphy**, geologic structure
  - ✓ **Lithology** of aquifers and confining layers
  - ✓ **Well inventory**
  - ✓ **Aquifer properties** (thickness, storage capacity, water table elevation, Hydraulic conductivity)
  - ✓ **Water Quality** (geochemical compatibility – source water and groundwater, clogging issues)
  - ✓ **Storage capacity**
  - ✓ **Groundwater velocity and direction**
  - ✓ **Distance to water source**
  - ✓ **Identify data gaps**
- **Engineering aspects**
- **Financial Considerations**
  - Cost Benefit Analyses
  - Factor in Maintenance
- **Regulatory**

END GAME:

✓ **Feasibility study**

✓ **Narrow your options**

Initial idea – 1995, Full implementation 2011
https://aquiferstorageandrecovery.weebly.com/case-study-1.html

Feasibility Assessment Report

Field Study and Conceptual Design

From Pyne, 2005

Field study

(More detailed hydrogeology)
Test drilling
Geophysics
Monitoring network
ASR well?
Aquifer tests
Chemistry

Conceptual design

Based on detailed information
Engineering
Cost

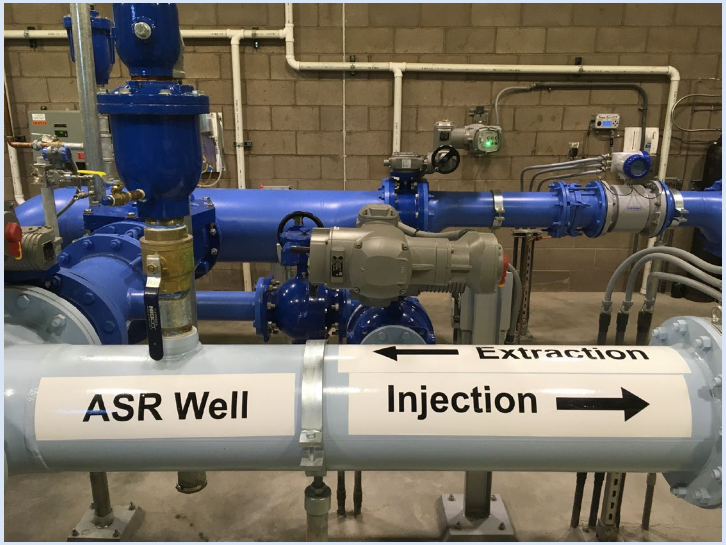
Pilot Project

Implementation and testing
Test equipment
Well efficiency

System Expansion

END GAME:

- ✓ **System feasibility analysis**
- ✓ **Design of pilot project**
- ✓ **Operating ASR well**



Aquifer Storage and Recovery - Summit Water Resources (summitwr.com)

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Aquifer Storage and Recovery (ASR)

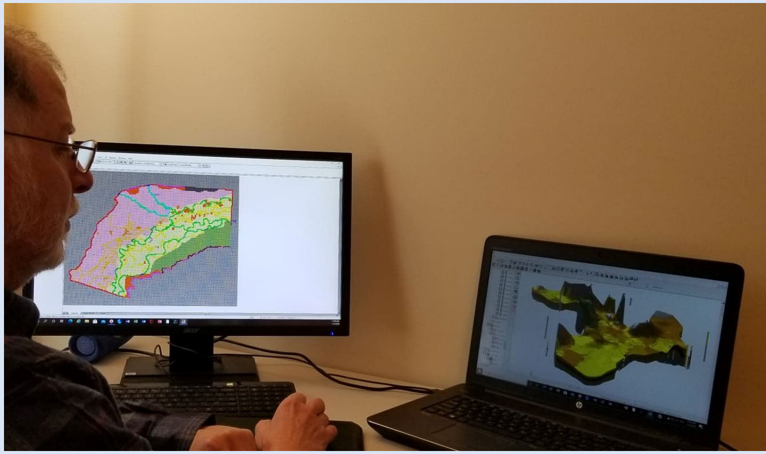
Hydrogeologic Modeling

Is data available to support this?

YES - Prior to Pilot Project

No - End of Pilot Project

- Hydraulic analysis of wellfield design and operations
- Analyze groundwater flow
- Geochemical simulation to evaluate interactions between native groundwater and stored water, changes in chemistry?



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Aquifer Storage and Recovery (ASR)

Pros

- Phased implementation
- Small storage footprint
- More protected than alternative storage technologies protected from evaporation, pollutants, and extreme weather events
- No potential for levee failure and downstream flooding
- Proven success
- Minimal affect on fisheries (does not effect fish passage)

Cons

- Initial characterization – will it work
- Reduced storage control
- Extractions limitation (regulatory)
- More energy intensive
- Chemistry/treatment issues (clogging)
- Maintenance and monitoring
- Expense

Aquifer Storage and Recovery (ASR)

ASR Operating Ranges

(from Pyne, NGWA MAR Conference, April 2023)

Well depths

- 150 – 2,700 ft

Storage interval thickness

- 20 – 400 feet

Storage Volumes

- 100 -270,000 acre-ft

Buffer radius <1,000 ft

Well capacity

- Up to 8 MGD (25 acre-ft/day) (individual wells)
- Up to 157 MGD (490 acre-ft/day) (well field)

2023

- ✓ At least 600 ASR wells
- ✓ In at least 140 ASR well fields
- ✓ 25 States
- ✓ Many different types of aquifers

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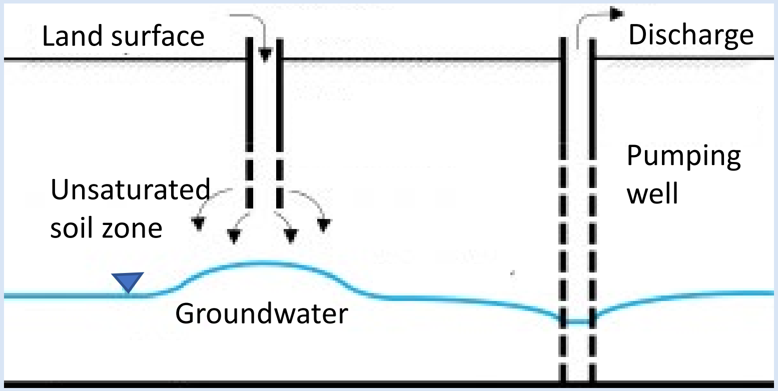
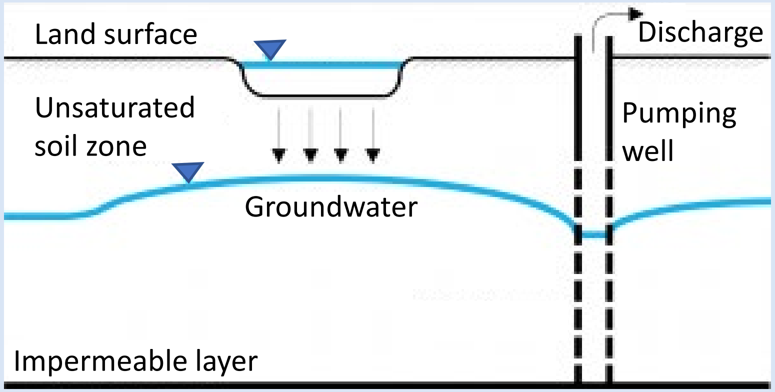
Hybrid Approach



AR to ASR



Innovative Groundwater Solutions [*Managed aquifer recharge – INOWAS (tu-dresden.de)*]

Vadose zone injection well

Useful if there are low permeability surface layers

Possible water treatment to prevent clogging

Infiltration Basin

Most applied

Unconfined aquifer

Possible water treatment to prevent clogging

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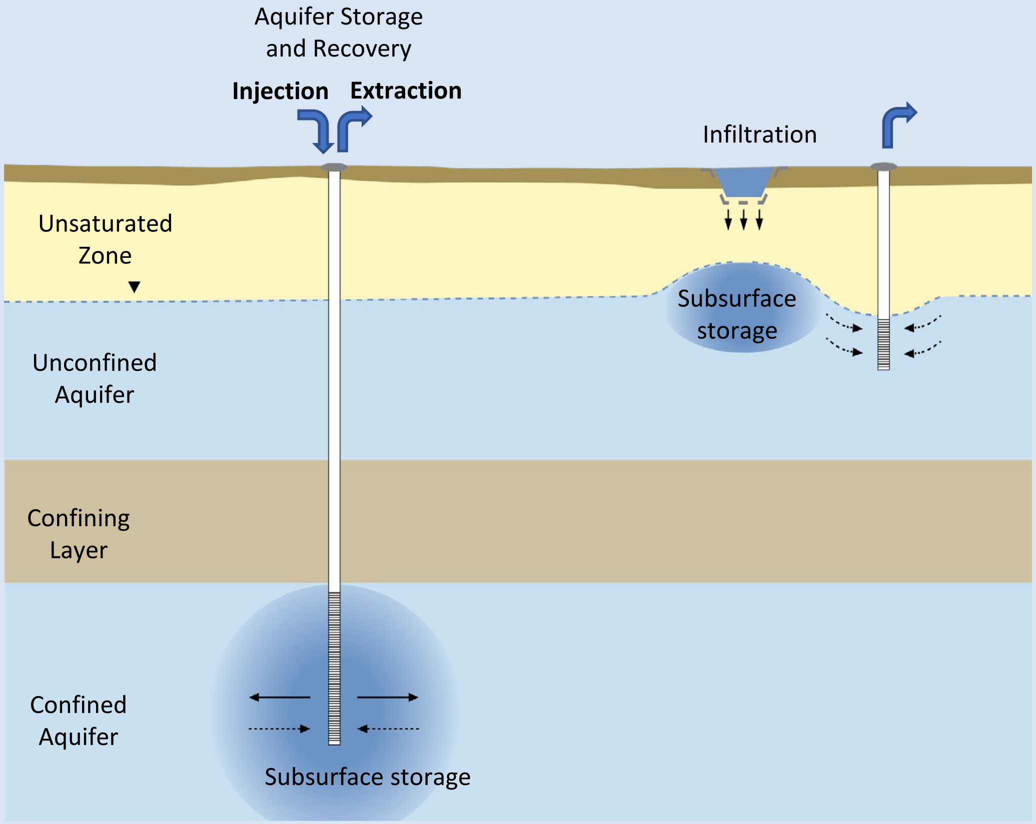
Suitability of MAR Sites

Multicriteria Decision Analysis – Hydrogeologic Considerations

Managed Infiltration

- Infiltration rate
- Type of aquifer
- Depth to water
- Aquifer thickness
- Aquifer storage
- Groundwater quality



Aquifer Storage and Recovery

- Storage Zone Depth
- Type of aquifer/properties
- Aquifer thickness
- Aquifer storage
- Degree of confinement
- Groundwater quality

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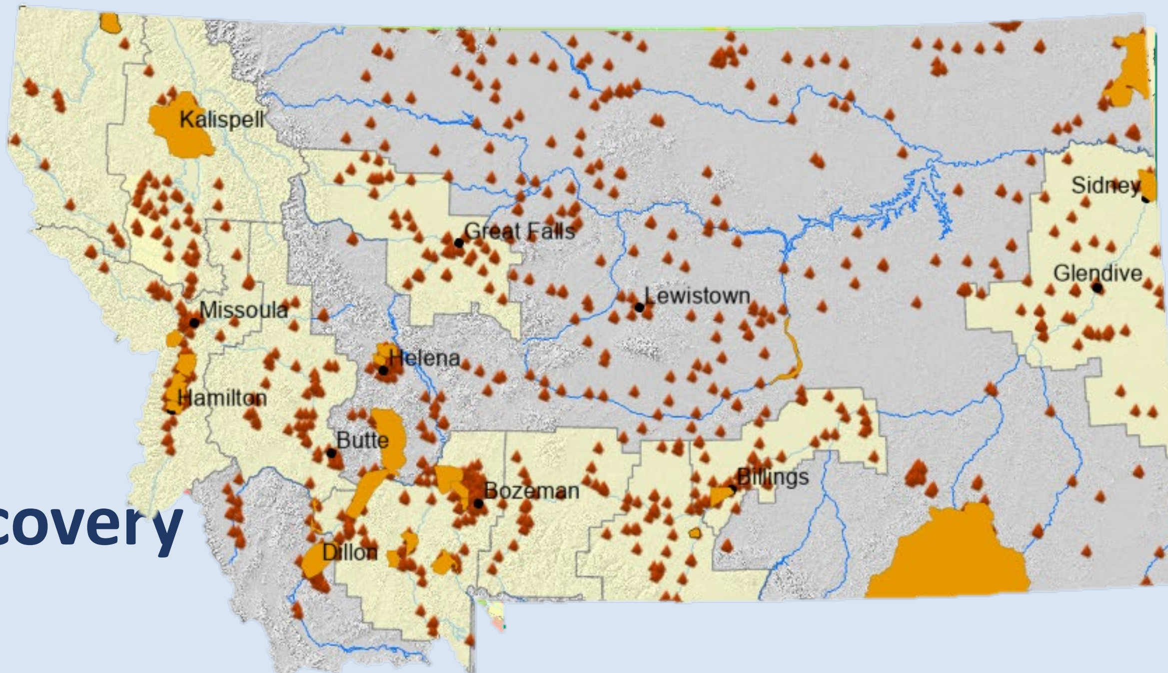
MAR For Montana – A suitability approach

Managed Infiltration

⬇

State-wide suitability map

(low, medium, high)



Aquifer Storage and Recovery

⬇

- Suitability map for Gallatin and Flathead Valley
- Up to 4 additional areas

Potential Locations

⬇

- Up to 12 sites more detailed GIS evaluation
- Up to 6 sites for a detailed hydrogeologic assessment

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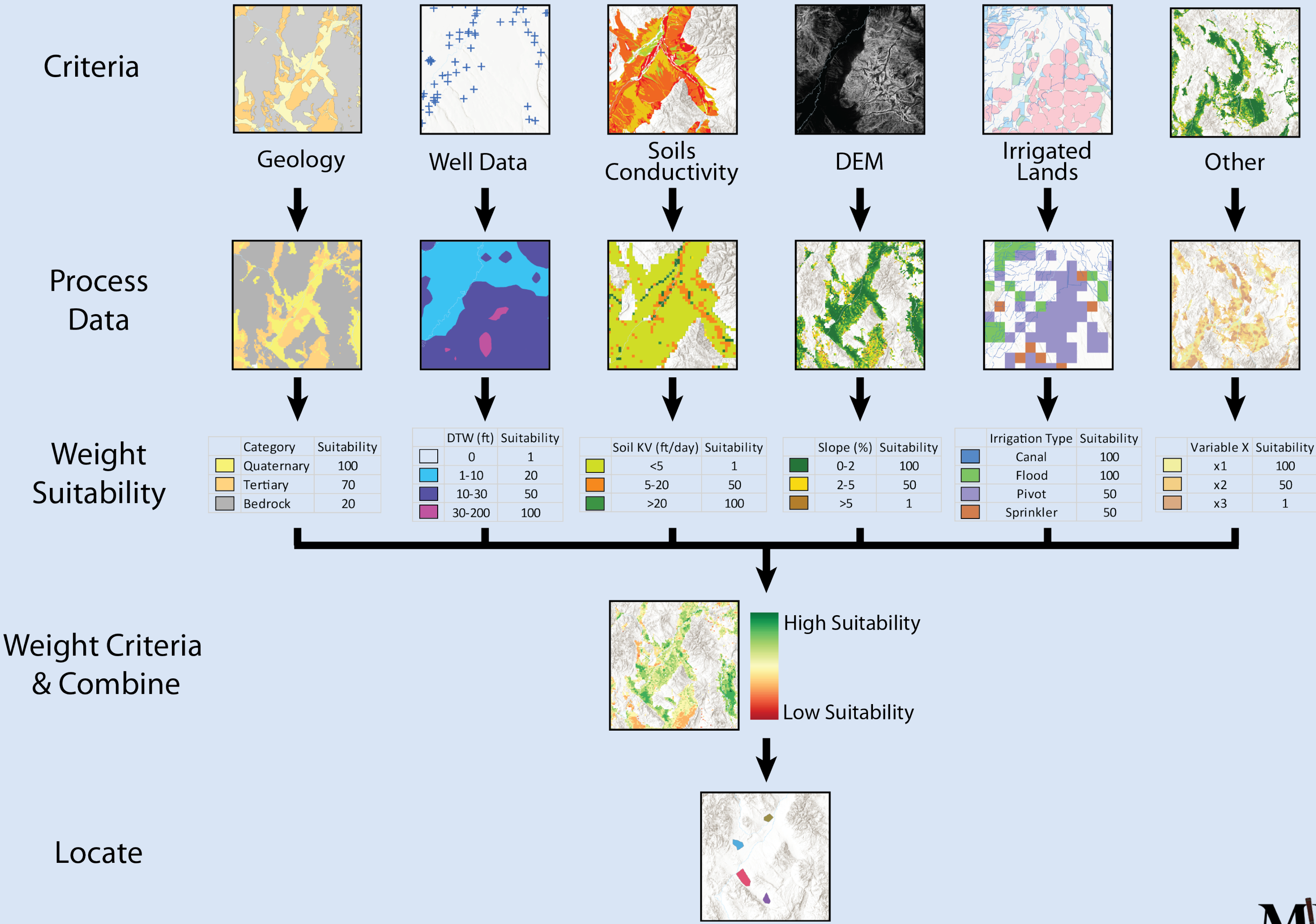
Suitability Criteria – Managed Infiltration



	Category	Suitability
	Quaternary	100
	Tertiary	70
	Bedrock	20

	DTW (ft)	Suitability
	0	1
	1-10	20
	10-30	50
	30-200	100

	Soil KV (ft/day)	Suitability
	<5	1
	5-20	50
	>20	100

	Slope (%)	Suitability
	0-2	100
	2-5	50
	>5	1

	Irrigation Type	Suitability
	Canal	100
	Flood	100
	Pivot	50
	Sprinkler	50

	Variable X	Suitability
	x1	100
	x2	50
	x3	1

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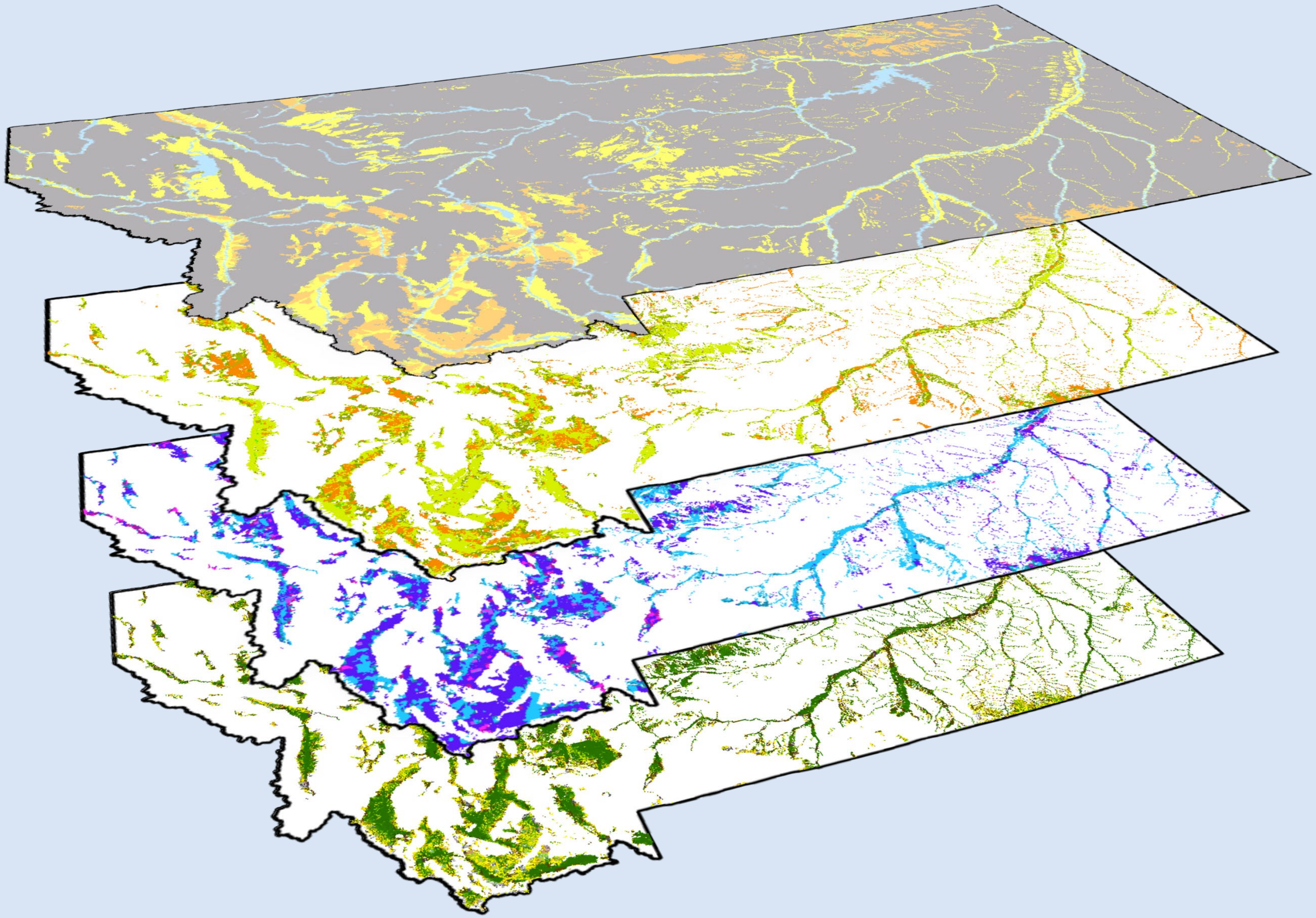

Simplified Geology
(MBMG)

Soil Hydraulic
Conductivity
(SSURGO)

Depth to Water
(GWIC)

Slope
(USGS DEM)

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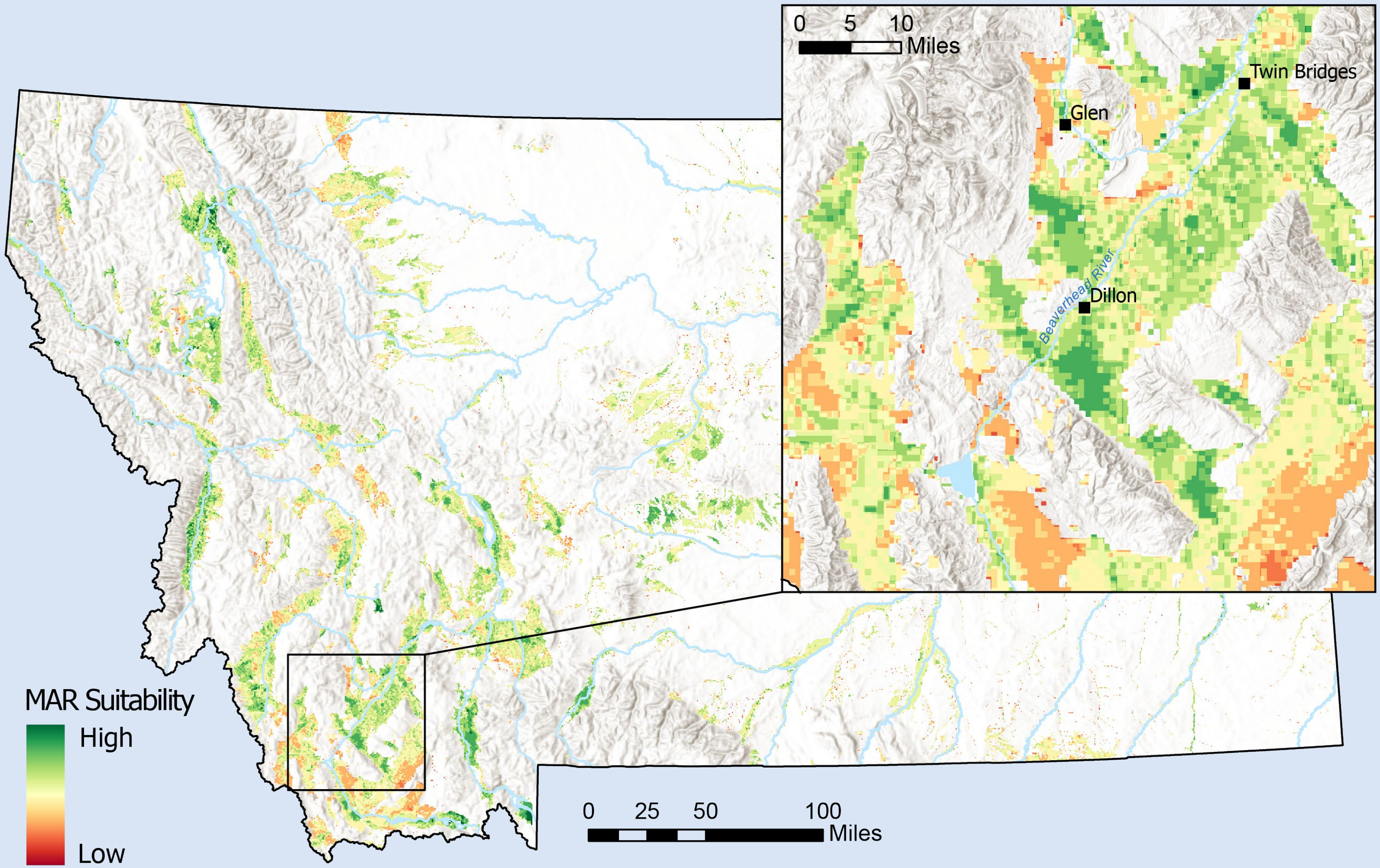

Information available on MBMG Data Portal (Web-Based Application)

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MAR for Montana

Be Strategic

- ✓ Suitability Mapping – consider scale
  - State-wide
  - Local
- ✓ Select Potential Sites
- ✓ Feasibility Study
- ✓ Pilot Project(s)

Benefits

- ✓ **Proactive adaptive strategy to address drought**
- ✓ **Supports Montana's water needs into the future**
- ✓ **Helps sustain groundwater and surface water resources**

Keep all options on the table

- ✓ Low Hanging fruit (Ag-MAR)
- ✓ More technical (ASR)

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